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Technical Memorandum 18-62

STUDIES ON THE PERCEPTUAL THRESHOLD FOR MOTION

II. EFFECTS OF INDUCED MOTION ON THRESHOLD VELOCITY

Charles Fried

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HUMAN ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND,
MARYLAND

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ABSTRACT

A proposed method for reducing threshold for perceived motion, by adding the force of induced movement to true movement, was explored. Induced movement was evidenced by (1) subjects reporting movement when no actual movement occurred, and (2) the increase in threshold when the direction of its influence was opposed to actual movement. The predicted threshold reduction, when the direction of actual and induced movement were identical, did not occur, because, presumably, the subjects attempted to compensate for the influence of induced movement.

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INTRODUCTION

The detection of movement has important implications in a number of military areas. This series of studies has attempted to isolate methods which will reduce the threshold of perceived motion below values ordinarily obtained.

The first report in this series (3) examined the effects of aperture dimension and proximity of a reference line on motion threshold. The results indicated that a reduction in aperture size will, for the smaller apertures, reduce the threshold. This result, in turn, appears to be a function of the distance of the moving object from a reference line, if the reference line is apparent to the subject.

The present study explores the possibility of applying a variation of the induced motion phenomenon to reduce threshold values.

Induced movement was first studied at length by Duncker (1) who distinguished it from two movement "types", real and phi movement. His apparatus for these studies consisted essentially of a dot in a surrounding frame of reference. When the frame was moved, the stationary dot appeared to move in the opposite direction. This phenomenon did not occur, however, when the subject "referred" the dot to a stationary frame.

Additional studies of induced movement by Oppenheimer (5) were concerned with the characteristics of perceptual objects most likely to become the frame of reference. Koffka (4) summarized this research and concluded that if one of two objects had the phenomenal function of framework for the other, it would be seen as stationary while the other moved, regardless of which object was actually moved.

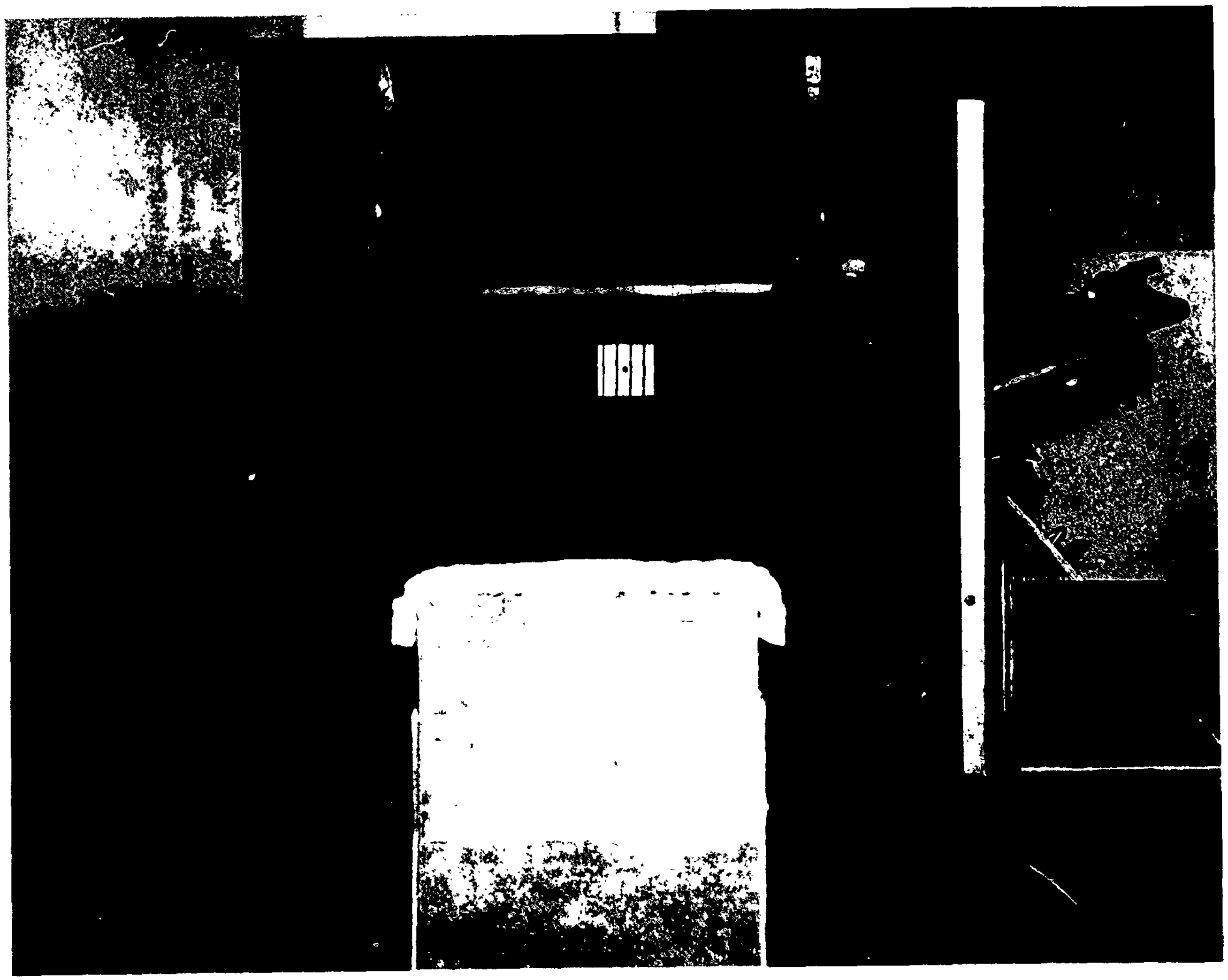

Fig. 1. VIEW THROUGH HOOD PLACED IN FRONT OF THE DISPLAY

METHOD

Apparatus and Procedure

A circular black dot, 4.76-mm. diameter, was painted on a sheet of transparent plastic and attached to a movable belt (Fig. 1). The belt was accelerated at a constant rate of .035 cm./sec.^{2} from zero velocity to a speed at which the subject (S) reported it as moving. A timer was started at the same moment that the transparent plastic began to move. The S indicated that he perceived the dot as moving by pressing a reaction button that stopped the belt and the timer. The experimenter, after recording the time elapsed, reset the timer and recentered the dot in the middle of the aperture.

The aperture was 8 x 8 cm., and the background was a white expanse, interrupted at 7.94-mm. intervals by 1.59-mm.-thick black vertical lines. Two fluorescent lamps gave background illumination of 30.13 millilamberts (ml.).

Chin and forehead rests were mounted in front of the hood to insure that Ss' eyes were 35.56 cm. from the display. The S viewed a dot in the center of a square aperture (Fig. 2). He could not see the rest of the apparatus.

To insure light adaptation, Ss viewed the display for a minimum of three minutes prior to the first test trial. During the adaptation period instructions were read, and practice trials were given. During the practice and test trials, Ss were required to fixate on the dot.

The method of limits, with ascending velocities only, was used to determine the threshold. Descending-velocity series would have been influenced by any motion aftereffects. The background remained stationary except in the induced movement trials, where it moved at a constant velocity of .271 cm./sec.

To prevent the S from responding to the time elapsed from the moment the belt began moving until he believed he should see motion, a number of dummy switches, starting audible motors, were turned on in the intervals between, and during, the test trials.

Fig. 2. SUBJECT AND EXPERIMENTER IN POSITION FOR A TEST TRIAL

Two blocks of five trials of each of the six conditions (two illuminations, stationary and moving backgrounds, and two directions of movement) -- a total of 60 trials -- were presented to each S. The blocks were given in a different randomized sequence for each S to minimize any systematic fatigue or learning effects.

Subjects

The Ss were 24 enlisted men of the Special Troops Battalion, Aberdeen Proving Ground, Md. All Ss had minimum near visual acuity scores of 20/20, as determined by Ortho-Rater test. The ages of the Ss ranged from 19 to 35.

Prior to the study, each S was tested on a simple reaction time device. The device consisted of a vertical line in the same position as the dot described above. The line was tilted from the vertical to a 45^{o} position almost instantaneously by a spring which simultaneously started a timer. The Ss were required to respond as early as possible to the line movement in three test trials. The mean of these test trials was used as the S's reaction time.

RESULTS

The experimenter recorded the time that elapsed from the start of the belt's motion until S indicated that he saw the dot moving. The mean reaction time for each S was then subtracted from the time scores, and these scores were converted into velocity values. The ten velocity values for each experimental condition were averaged for each S, and this mean value was used in the analysis.

After completing the analysis of variance for randomized blocks with each S regarded as a block in the design (2), Duncan's Multiple Range Test was used to evaluate the differences between the means (Table 1 and Table 2).

TABLE 1

Analysis of Variance for Six Experimental Conditions
with 24 Subjects in Each Condition

Source of Variance	Sum of Squares	df	Mean Square	F
Between Conditions	32,047.44	5	6,409.49	15.10*
Between Subjects	91,030.86	23	3,957.86	9.32*
Conditions x Subjects	48,804.85	115	424.39	
TOTAL	171,883.15	143		

* $p < .01$

At the .05 level of confidence, there was no significant difference between the room-illuminated, unrestricted field-of-view condition, and the low-illumination, restricted field-of-view condition. This finding was true for all background movement conditions, i.e., stationary, motion opposite to dot, and motion in same direction as dot.

Increasing room illumination and providing S with a larger field of view, with a presumably stable frame of reference, did not influence the threshold.

There was a significant difference between the two directions of background movement. The threshold was significantly higher when the background and the dot moved in the same direction.

In comparing the effects of background movement, irrespective of direction, a moving background raised the threshold over the values obtained with a stationary background. There is a greater increase in threshold when the background movement is opposed to the dot's direction of movement (Fig. 3).

TABLE 2

Duncan's Multiple Range Test Applied to the
Differences Between the Six Experimental Condition Means

	Stationary Background		Moving Background			
			Moving in Opposite Directions		Moving in Same Direction	
Means	Unrestricted Field (1)	Restricted Field (2)	Unrestricted Field (3)	Restricted Field (4)	Restricted Field (5)	Unrestricted Field (6)
(1) 33.82		4.01	17.77	22.08	36.08	40.30
(2) 37.83			13.76	18.07	32.07	36.29
(3) 51.59				4.31	18.31	22.53
(4) 55.90					14.00	18.22
(5) 69.90						4.22
(6) 74.12						
Means	33.82	37.83	51.59	55.90	69.90	74.12

(Any two treatment means not underscored by the same line
are significantly different at or beyond the .05 level.)

TABLE 3

Means and Variances for Six Experimental Conditions

	Stationary Background		Moving Background			
			Moving in Opposite Directions		Moving in Same Direction	
Means	Unrestricted Field	Restricted Field	Unrestricted Field	Restricted Field	Restricted Field	Unrestricted Field
Mean	33.82	37.83	51.59	55.90	69.90	74.12
Variance	308.35	307.30	1,084.38	1,004.26	1,805.40	1,315.51
n	24	24	24	24	24	24

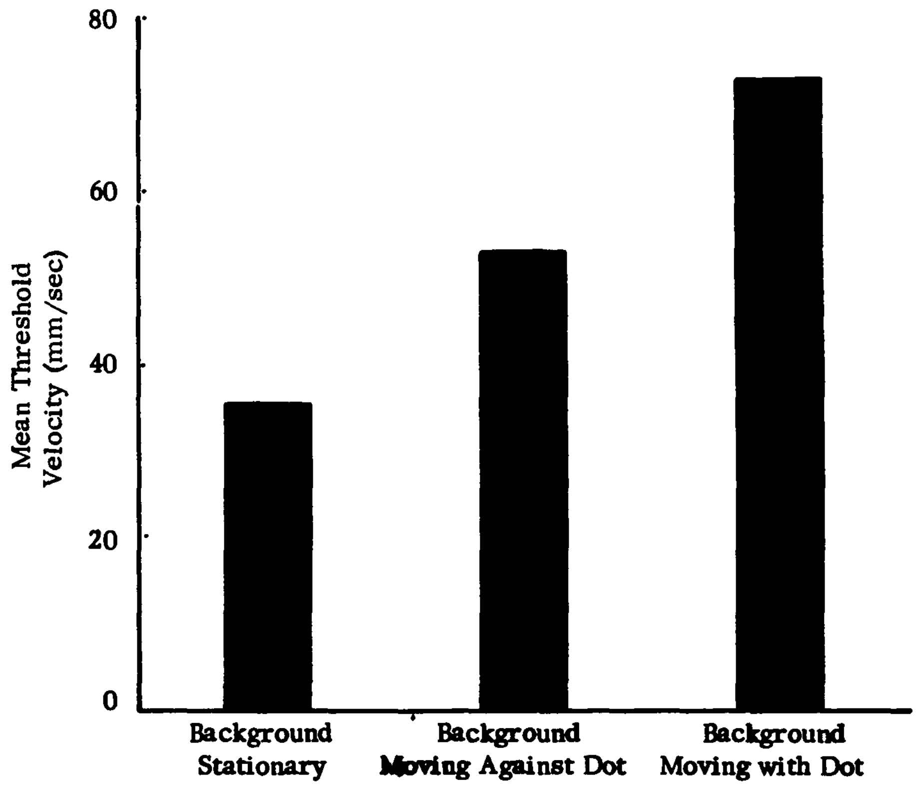

Fig. 3. MEAN THRESHOLD VELOCITIES FOR MOVING DOT AGAINST A STATIONARY AND MOVING BACKGROUND

DISCUSSION

Illumination

This variable was included to insure that any findings about background movement would not be limited to the restricted field-of-view conditions commonly used in investigating perceptual thresholds. Duncker (1) found that the introduction of stable frames of reference, in addition to the one that caused the induced motion, would invariably eliminate or reduce the induced motion effect. When the stable frame was visible, his Ss reported that they "referred" the dot to the non-moving frame. As a result, they did not see any movement. However, one difficulty is that it is not always possible to predict when the Ss will "refer" the dot to alternate frames. It is conceivable that the Ss will use the most striking and "impressive" frame of reference available. Since moving vertical lines are attention-getting even in the brightly lit room, a S may persist in using them as a reference for the moving dot. Duncker, however, used relatively neutral cardboard squares to create the induced motion illusion. These squares were not effective when the S was able to see the entire room and use the more "impressive", stationary walls for the frame of reference.

Direction of Movement

The direction of background motion significantly influenced the threshold, and thresholds were consistently higher when the direction of movement of the background and dot were the same. This effect could be predicted from the direction in which induced movement operates, i.e., the dot is always "moved" opposite in direction to the background's motion. When the directions of the two movements are opposed and the forces of actual and induced motion "interfere" with one another, a larger amount of real movement is necessary before a threshold value is reached. On the other hand, when the background is moving in a direction counter to the dot's motion, the forces of the actual and induced motion are aligned and the threshold is lowered.

Movement vs. Stationary Background

A background of moving vertical lines significantly increased the threshold, as compared to when the vertical lines were stationary. The threshold should be increased when the background moves counter to the dot and the forces of real and induced motion are in conflict. When the forces of real and induced motion are identical in direction, it might be expected that phenomenal movement would be increased and the threshold would be reached with a smaller amount of real movement.

However, an unexpected increase in threshold occurred when the background moved against the dot, although the increase was not so large as when the background moved with the dot. This result may be attributed to a procedure used in the study. For all movement trials, the background remained in motion, even during the period between tests when the dot was not in motion. This control was necessary because Ss might respond solely to the background's motion if it started at the same time that the dot was placed in motion. Unfortunately, this procedure led to a number of reports that the stationary dot was moving, because of the effects of induced motion. The Ss were cautioned repeatedly to respond only when they were certain that the dot moved, and this instruction may have made them overly cautious about reporting motion. Caution is an organismic variable, and it may be expected that the experimental conditions of moving background vs. stationary background will be reflected in the variances of the two groups, with a significant increase in variance for the moving background (note discussion by Edwards [2], p. 110).

The means and variances for the six experimental conditions are presented in Table 3. F tests for homogeneity of variance were performed between all conditions, contrasting stationary and moving background. In all four of the possible comparisons, the variance for moving background was significantly greater at the .01 level of confidence. This finding supports the view that an increase in caution was responsible for the increased threshold under conditions of background movement.

SUMMARY

The effects of induced motion were added to actual motion of a dot to ascertain if the threshold for motion could be reduced to levels below those ordinarily obtained.

Three comparisons were made: (1) the effects of a background of movement on the threshold for movement; (2) for the movement trials, a comparison of the direction of movement of the background on the threshold, i.e., in a direction opposite to or similar to the dot's movement; (3) a restricted and darkened field of view, as compared to an unrestricted view and a room illumination of 102.22 ml. A hood, placed in front of the display, was used to restrict and darken the field of view. This last variable is of interest, as Duncker (1) had found that inclusion of stable frames of reference in the field of view reduced the induced-motion effect.

Room illumination and field of view had no effects upon threshold. A moving background resulted in sizable induced-motion effects, which served to raise the threshold when the induced motion was opposed to the actual motion. When the directions of the actual and induced movement were the same, the threshold was also increased. An explanation in terms of the Ss' caution in reporting motion was offered to account for this last result.

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